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An overview of the early development of the first genetically engineered crop- derived foods

Nicolau B da Cunha[1], Michel L Leite[1], Lorena S L Costa[1], Victor A Cunha[1], Simoni C Dias[1], Giovanni R. Vianna[2], Elíbio L. Rech[2]

[1]*Centro de Análise Proteômicas e Bioquímicas de Brasília, Universidade Católica de Brasília, Programa de Pós-Graduação Stricto Sensu em Ciências Genômicas e Biotecnologia, Universidade Católica de Brasília SGAN 916, Av. W5, Brasília, DF, Brazil.*
[1]*Centro de Análise Proteômicas e Bioquímicas de Brasília, Universidade Católica de Brasília, Programa de Pós-Graduação Stricto Sensu em Ciências Genômicas e Biotecnologia, Universidade Católica de Brasília SGAN 916, Av. W5, Brasília, DF, Brazil.*
[1]*Centro de Análise Proteômicas e Bioquímicas de Brasília, Universidade Católica de Brasília, Programa de Pós-Graduação Stricto Sensu em Ciências Genômicas e Biotecnologia, Universidade Católica de Brasília SGAN 916, Av. W5, Brasília, DF, Brazil.*
[1]*Centro de Análise Proteômicas e Bioquímicas de Brasília, Universidade Católica de Brasília, Programa de Pós-Graduação Stricto Sensu em Ciências Genômicas e Biotecnologia, Universidade Católica de Brasília SGAN 916, Av. W5, Brasília, DF, Brazil.*
[1]*Centro de Análise Proteômicas e Bioquímicas de Brasília, Universidade Católica de Brasília, Programa de Pós-Graduação Stricto Sensu em Ciências Genômicas e Biotecnologia, Universidade Católica de Brasília SGAN 916, Av. W5, Brasília, DF, Brazil.*
[2]*Laboratório de Agricultura Tropical,Embrapa Recursos Genéticos e Biotecnologia, Parque Estação Biológica, PqEB, Av. W5 Norte (final), Brasília, DF, CEP 70770-900, Brazil.*
[2]*Laboratório de Biologia Sintética, Embrapa Recursos Genéticos e Biotecnologia, Parque Estação Biológica, PqEB, Av. W5 Norte (final), Brasília, DF, CEP 70770-900, Brazil.*
CorrespondingAuthor: Nicolau B Da Cunha

--***ABSTRACT***--
Transgenic plants represent one of the greatest scientific advances produced by genetic engineering. The first generation of transgenic plants aimed to obtain vegetables with improved agronomic characteristics, such as higher biomass productivity, pest resistance and herbicide tolerance. The second generation of genetically modified plants, however, aims at increasing nutritional and organoleptic properties and lower indices of antinutritional and allergenic factors. Genetically engineered plant products hit the shelves of US supermarkets in the first half of the 1990s. Since then, products derived from corn kernels, canola, and other plants have been approved for cattle feed and human consumption. This mini review aims to report an overview of the early development of the first genetically engineered functional foods and to put into perspective their great importance for obtaining more nutritious and healthy foods.
KEYWORDS;*Genetically engineered foods, human nutrition, nutrient increased crops*

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I. INTRODUCTION

Transgenic plants required by the food industry or the increase in the nutritional quality of the human diet are part of the so-called second generation of transgenic organisms and constitute one of the most important niches of transgenic products related to agriculture.

Most vegetables consumed by the population are deficient in certain essential amino acids that cannot be synthesized by the human body. Cereals such as rice (O. sativa) and wheat (T. aestivum) are low in lysine and threonine, while vegetables such as peas (P. sativum) and beans (P. vulgaris) are deficient in methionine and cysteine.

The fatty acid content of oilseeds consumed or used in food preparation is also low in oils used as important nutrients, related to various metabolic functions, cardiovascular health, blood pressure regulation and inflammatory response.

The development of more nutritious genetically modified foods advocates the production of transgenic plants containing increased levels of biomolecules used as nutrients or functional metabolic effectors in the

human organism, such as amino acids, proteins, fatty acids, carbohydrates and vitamins, or only that have increased their levels. natural bioavailability and decrease of nutrient chelators and allergenic compounds.

The first example of genetically altered food obtained in the laboratory to reach the consumer effectively was tomato (L. esculentum) FlavrSavr®, developed in 1994 by Californian biotechnology company Calgene. A year later the product was released for regular marketing by the USDA.

Tomato plants, as well as other fruiting plant species, contain in their genome a gene encoding the enzyme Polygalacturonase (PG), responsible for catalyzing the digestion reaction of a structural carbohydrate present in the cell wall of fruits, called pectin. The progressive conversion of pectin to simpler carbohydrates leads to the natural ripening of the fruit followed by its decay, able to facilitate the release of seeds for plant propagation.

TomatoesFlavrSavr® contained copies of the PG gene in complementary orientation to conventional sequences, leading to the obtaining of complementary copies of mRNA complementary to each other after the gene transcription process.

Duplex mRNA molecules are naturally inactivated by endogenous molecular mechanisms triggered by the plant's own metabolism, resulting in a marked decline in PG biosynthesis.

Thus, tomatoes FlavrSavr® presented only basal or insignificant PG enzyme levels, sufficient to guarantee an altered phenotype of long-term maintenance of the concentration of pectin molecules in the fruit cell cell wall, responsible for considerably delaying the ripening process.

FlavrSavr® fruits took about twice as long to rot as conventional tomatoes, could be stored for more than three weeks at room temperature and did not need to be harvested green and rigid nor transported at low temperatures to maintain their quality and flavor conservation (hence your name).

Despite the undeniable scientific and commercial advancement in FlavrSavr® technology, problems with adapting harvesting machinery, the low number of transgenic cultivars adapted to different producing regions and, mainly, public skepticism about paying higher prices for the product, led to technology abandonment in 1996, followed by the purchase of Calgene by biotech giant Monsanto.

In 1995, Calgene launched a transgenic variety of canola (B. napus) containing a gene from the Umbellulariacalifornica plant (Hook. &Arn.) Nutt. (belonging to the laurel family), encoding a thioesterase that catalyzes the biosynthesis of lauric acid, a 12-carbon, fully saturated, acyl-greasy tail fatty acid normally found in low concentrations in canola seed oil is considered healthier and with better cooking properties than conventional oils mainly derived from soybean (G. max) and sunflower seeds.

Transgenic canola has 40% of its oil composition due to the accumulation of lauric acid and is still one of the best examples of good acceptance by the public, especially in the United States.

The most representative biotechnological example involving the nutritional enrichment of a food by genetic engineering was the development of transgenic rice (O. sativa) plants by the group of Germans Ingo Potrykus and Peter Breyer, respectively from the Institute of Plant SciencesSwiss Federal Institute of Technology (ETH), Zurich (Switzerland) and the University of Freiburg (Germany) in late 1990s, containing the genes encoding the enzymes phytoene synthase and phytoene desaturase (originating from the plant Narcissus pseudonarcissus L.) and the gene lycopene op-cyclase of the bacterium Erwinia uredovora, responsible for the reconstitution of the provitamin A anabolic pathway, called β-carotene, a precursor to retinol (vitamin A itself).

The accumulation of this yellowish pigment in high concentrations in the grain endosperm of the most promising transgenic lines was more than 1.5µg of the molecule per gram of dry grain, enough to give the yellowish hue to the inflorescences of the transgenic plants, called "Golden Rice". or Golden Rice.

Pediatric vitamin A deficiency is the most important but preventable cause of childhood blindness - a disease that strikes about 500,000 children a year in 26 countries and, at acute levels, contributes to the deaths of 2 million children in underdeveloped nations. annually.

As β-carotene is an indispensable precursor for the biosynthesis of vitamin A by the human organism, rice forms the staple diet of populated Asian, American and African countries and there is no identified rice germplasm able to synthesize the nutrient for use in conventional breeding programs, transgenic plants such as Golden Rice are the only options to fill these biotechnological gaps.

The Golden Rice project was funded primarily by the American Rockefeller Foundation and has philanthropic purposes, which involves the abolition of technological royalties for farmers and logistical and product distribution facilities.

After Potrykus's retirement, Breyer was able to obtain new, more efficient transgenic strains by replacing the narcissus phytoene synthase gene (N. pseudonarcissus) with his maize analog (Z. mays), which enabled 23-fold higher accumulation of β- carotene in the beans, resulting in the Golden Rice II variety.

By assessing the levels of β-carotene accumulation achieved in Golden Rice II grains, it was estimated that the daily intake of 72 grams of polished grains of this transgenic variety is enough to provide 50% of the recommended nutritional intake of vitamin A.

Despite the social character, biotechnological ingenuity and experimental elegance of the project, well-organized opposition by non-governmental entities and bureaucratic and regulatory difficulties prevented the arrival of the product to farmers and, a decade after its development, Golden Rice It is still a biotech promise to come true no earlier than 2011 according to the most optimistic forecasts.
Several other examples of genetically modified plants present in food and useful for the food industry as well as for academic purposes were obtained from the 1990s (Table 1).

Table 1: Examples of GM plants with potential use in the food industry

Transgenic plant	**Origin of the gene**	**Recombinant protein expressed (E), overexpressed (SE) or suppressed (S)**	**Phenotype change**
Melon	Melon	aminocyclopropane carboxylate oxidase (S)	Decreased ethylene production. Increased shelf time
Broccoli	Broccoli	aminocyclopropane carboxylate oxidase (S)	Decreased ethylene production. Increased shelf time
Tomato, lettuce, potatoes and watermelon	Plants Dioscoreophyllumcumrninsii and Thaumatococcusdaniellii	Monelin (E) thaumatin (E)	Increased sweetish flavor
Maize	Plant Pentadiplandrabrazzeana	Brazeine (E)	Increased sweetish flavor
Apple and potato	Apple and potato	Polyphenol oxidase (S)	Reduction of oxidation after cutting (brown spots)
Wheat	Wheat	High molecular weight glutenins (SE)	Increased elasticity and strength for baking
Potato	Potato	Starch synthase (S)	Absence of amylosis, facilitated preparation in microwave
Potato	Klebsiella pneumoniae (Bacteria)	Cyclodextrin glycosyltransferase (E)	Increased production of cyclodextrins, enhancing odor and flavor
Potato	E. coli(Bacteria)	ADP-glucose pyrophosphorylase (E)	Increase by 60% in the concentration of starch
Potato	Potato	AGPase (S)	Abolition of starch production, 30% increase of sucrose accumulation and 8% glucose
Potato and Tobacco	Bacillus subtilis(Bacteria)	Frutosyltransferase (E)	Accumulation of fruit sugar (8% in tobacco leaves and 7% in potato tubers)
Beet	Sunflower potato, onion	sucrose fructosyltransferase and fruthane 6G fructosyltransferase (E)	Obtaining fruitans in tubers above 110μmol/g in tuercules1
Wheat	Wheat	starch branching enzyme	More than 70% increase in the content of amylose in grain
Tobacco	E. coli(Bacteria)	trealose-6-phosphate synthase and trealose-6-phosphate phosphatase (E)	Production of food stabilisertrehalose
Rice and wheat	Pea	Legumin (E)	Increased lysine
Lippin	Sunflower	Albumin (E)	Increased methionine
Potato	Amaranthus hypochondriacus (Plant)	Albumin (E)	100% increase in protein content and essential amino acids
Arabidopsis	E. coli(Bacteria)	dihydrodipicolinate synthase and aspartate kinase (E)	Increased lysine content by 80 times in seeds
Corn, canola and soy	E. coli(Bacteria)	dihydrodipicolinate synthase (E)	Increased lysine content to 30% of total seed amino acids
Rice	Rice	anthranilate synthase (E)	100% increase in tryptophan content in grains
Maize	Maize	Zein (SE)	Increased methionine
Arabidopsis	E. coli(Bacteria)	Δ9-elongase, Δ8-deaturase, and Δ5-deaturase (E)	Increase in eicosapentenoic (3% total) and arachidonic (6.6% total) fatty acids

Tobacco and flax	Mortierellaalpina(Fungus), Phaeodactylumtricornutum (Algae); Physcomitrellapatens(Bryophyte),Boragoofficinalise(Plant),C. elegans(Nematoid)	deaturases Δ5 and Δ6 and Δ6-elongase (E)	Increase of long chain polyunsaturated fatty acids (25% total seeds)
Arabidopsis	Zebrafish and Pavlova saline(Seaweed)	Δ5 and Δ6 deaturases (E)	Accumulation of docosaexaenoic acid (0.5% total)
Soy	Mortierellaalpina and Saprolegniadiclina (Fungi)	Δ6-elongase and ω3 microsomaldesaturase (E)	Accumulation of docosaexaenoic acid (3% total)
Mustard	Phytophtorainfestans and Thraustochytrium aureum(Fungi)and Calendula officinalis(Plant)	ω3 desaturaseand Δ12-deaturase acyltransferase (E)	Long-chain polyunsaturated fatty acids
Potatoes, cauliflower, carrots, canola and tomatoes	Erwinia herbicola(Bacteria)	phytoene synthase phytoene desaturase lycopene β-cyclase (E)	Increase in β-carotene ("Yellow potato" and "orange cauliflower")
Arabidopsis	Arabidopsis	γ-tocopherol methyltransferase (SE)	Accumulation of α and β-tocopherols (components of vitamin E)
Soy	Arabidopsis	2-Methyl-6-phytylbenzoquinol methylltransferase and γ-tocopherol methylltransferase (E)	8-fold increase in the accumulation of α tocopherol
Tomato, rice and Arabidopsis	E. coli bacteria	GTP cyclohydrolase I (E)	folate
Tobacco	Mouse Wheat	L-gulonolactone oxidase and dehydroascorbate reductase (E)	Ascorbate (vitamin C)
Tomato	Tomato	malate dehydrogenase (E)	Increase Ascorbate build-up by 6 times
Rice	Barley	nicothianamine aminotransferases (E)	Increased use of iron.
Rice	Soy	ferritin (E)	Grains with 4 times more bioavailable iron
Rice, peanuts and potatoes	Rice, peanuts and potatoes	Modification of epitopes of allergenic proteins	Increased food tolerance
Turnip	Turnip	UDP-GLC:synapate glycosyltransferase (S)	76% reduction in levels of toxic synapate esters in seeds
Cassava	Cassava	Enzyme cytochrome P450 (S)	92% reduction in cyanogenic glycosides levels
Potato	Leaven	Invertase (E)	Reduction of toxic glycoalkaloids
Coffee	Coffee	Caffeine synthase (S)	Decreased caffeine levels

Adaptedby Zhu et al., 2007.

II. CONCLUSION

The development of the first genetically engineered functional foods was important to show to public opinion the potential of transgenic organisms not only for the agricultural sector but also for human health and nutrition. The first most nutritious transgenic plants with the least antinutritional and allergenic factors showed different degrees of commercial success and public acceptance. This was due to a number of factors such as poor marketing, difficulties in disseminating science to the general public, anti-GMO campaigns and the novelty factor for the public, which is naturally more refractory to technological innovations involving aspects of human nutrition. Despite some drawbacks, early genetically engineered foods have opened the market for new versions

of fruits, seeds and leaves that carry bioactive molecules with great potential for the nutritional enhancement of the human diet. These new foods should gain more shelf space in supermarkets and become popular in the long run..

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